Title: Mshock, a thin layer Richtmyer-Meshkov instability experiment

Author(s): Desjardins, Tiffany; Merritt, Elizabeth Catherine; Flippo, Kirk Adler; Kline, John L.; Di Stefano, Carlos; DeVolder, Barbara Gloria; Doss, Forrest William; Fierro, Franklin; Randolph, Randall Blaine; Schmidt, Derek William; Wilson, Christopher Talker

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T. Desjardins, E. Merritt, K. Flippo, J. Kline
P-24: Plasma Physics

C. Di Stefano, B. DeVolder, F. Doss

XTD-IDA: XTD Integrated Design and Assessment

F. Fierro, R. Randolph, D. Schmidt, C. Wilson

MST-7: Engineered Materials
Los Alamos National Laboratory
tif_des@lanl.gov

Abstract

The Mshock campaign is studying the feedthrough of the Richtmyer-Meshkov instability (RMI) in a thin layer in the high energy density (HED) regime. Experiments utilize a beryllium shock tube filled with low density foam and a high density plastic to study the instability. Initial experiments were performed at the OMEGA laser facility and recently at the National Ignition facility. While the basic design of the experiment is the same, critical components were changed to optimize the data quantity and clarity for the more energetic NIF.

I. Introduction

The *Mshock* campaign is seeking to study the Richtmyer-Meshkov instability (RMI) and feedthrough effects in a high energy density (HED) regime. The experiment utilizes a shock tube geometry similar to previous gas curtain experiments, but on the millimeter scale size. The interior of the shock tube is filled with a low density plastic (CH) foam and a thin piece of iodinated plastic (CHI) placed near the center of the shock tube. Seed perturbations are machined onto the surface of the high density layer to induce further mixing. By changing the initial conditions and shock timings we are able to affect the growth rate and enhance (or inhibit) the amount of mixing.

We have completed experiments in a simple shock then re-shock experiment at the OMEGA laser facility, the details of which can be found in Desjardins *et al.* [1]. Similar experiments are now being conducted at the National Ignition Facility. This paper will highlight changes from the OMEGA platform to the NIF campaign.

II. NIF Experiment

The NIF facility is comprised of 192 laser beams that can each supply up to ≈ 7 kJ of energy/beam using an indirect drive scheme, whereby the lasers impinge on the walls of a gold hohlraum (or halfraum). Our current drive setup at either halfraum uses sixty laser beams at 303 kJ supplied over a 10 ns time period to provide a supported shock. The generated radiation bath drives shocks at the ablators with a velocity $v = 150$ μm/s ($M \approx 14 - 28$, where 14 is assuming solid densities, and 28 assumes all materials are a plasma with electron temperature T_e = 10 eV). The increased energy at the NIF compared to OMEGA enables increasing the size of the target, and thereby allows us to enhance our radiographic spatial resolution and measure other-wise unresolvable

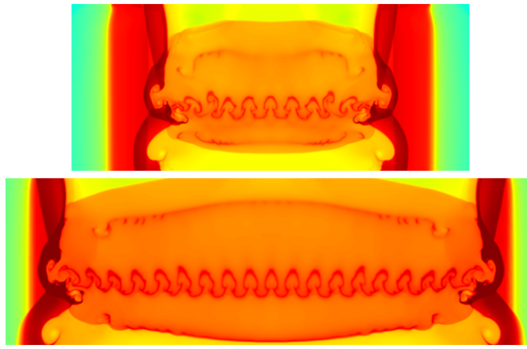

Figure 1: *The walls of the shock tube negatively impact nearby features, making it necessary to increase the overall diameter of the shock tube.*

mixing structure. NIF targets were designed based on the OMEGA target and the well-tested NIF *Shear* platform, but were initially increased by approximately a factor of three.

The original OMEGA tube diameter was 0.5 mm, meaning that the new tube width was planned to be 1.5 mm. However, as shown in Figure 1, simulations indicated that the walls would have a negative impact on nearby features, limiting the region of interest. To counter this effect, the overall diameter of the shock tube was increased. There are two major limitations on the tube diameter. The first is the available field of view with the diagnostics at the NIF. From the previous *Shear* experiments [2], we are able to calculate that we have a field of view 2.4 mm in height. The second limitation is caused by diagnostic imaging setup. As at OMEGA the primary diagnostic is x-ray radiography, but the NIF setup uses the big area backlighter (BABL) design [3]. A two pinhole imaging system is used to capture two time sequences per shot. The high density layer uses a strip doping profile as shown in Figure 2.

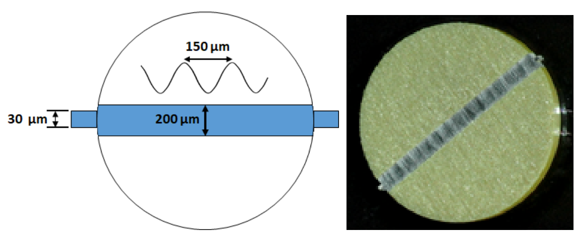

Figure 2: *An iodine dopant is added to the high density layer in a central profile to increase contrast with the foam while also reducing the visibility of any edge effects.*

This doped profile serves two purposes. The dopant itself improves the contrast between the high density layer and the undoped foam reduces the effect of the line integration and enables the measurement of individual features. By applying the dopant in a strip we are able to observe only a thin region of the layer as the RMI grows, which should make imaging of individual features possible. The dopant used is iodine at a value of 3% atomic, which has a density of $\rho_0 = 1.45$ g/cc. The undoped portion is machined PAI, with a density of ρ_0 = 1.4 g/cc. The current thickness is 200 μm, but can be varied to adjust the contrast between the foam and the high density layer, with 100 μm thick being the thinnest with current machining techniques.

While CH is relatively transparent to x-rays, above 1 mm in thickness the transmission can start to significantly attenuate x-rays. One solution to this problem is to use a high-Z material as a backlighter. However, this means that the conversion efficiency goes down and fewer photons are produced with the same energy drive. With the available energy at the NIF, a zinc backlighter is the highest Z material that we could use and obtain a usable image; the lowest Z we considered was iron, placing the energy range of the x-rays between 6.7 – 9 keV.

We have two requirements we need to meet for our transmission. First, we need to maintain as sharp a contrast between the low density foam and the high density layer, as well as between the PAI and the iodine doped strip. While increasing the width of the tube does increase the integration path length, the low density CH foam does not significantly contribute to the x-ray attenuation. Increasing the diameter from 1.5 mm to 3 mm only causes a 6% decrease in the transmission through the foam.

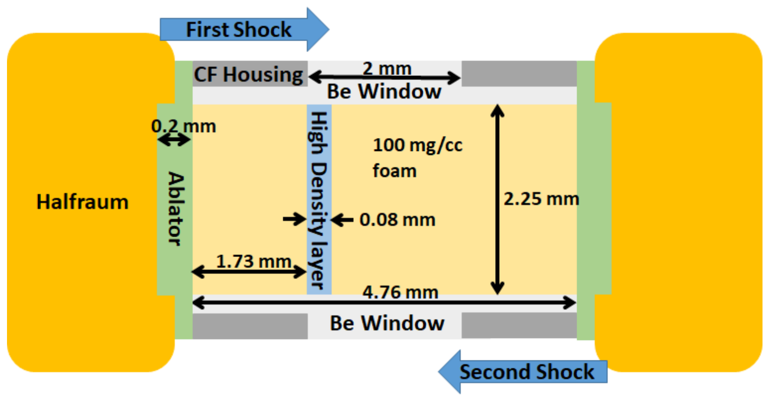

Figure 3: *The NIF target is 4.76 mm long cylinder, with a 2.25 mm inner diameter and 3.05 mm outer diameter. A beryllium top hat provides a congruent shock tube, with a large beryllium window spanning the experimental region of interest. A fluorinated plastic (CF) housing encompasses the ends and connects to the gold halfraums used in the indirect drive.*

However, the transmission through the PAI material that surrounds the doped strip is quite sensitive to increases in tube diameter, i.e. changing from a 1.5 mm to 3 mm diameter leads to a 25% change in transmission. To ensure that we are only imaging the iodine doped region, we need the transmission through the PAI to be higher than through the iodine doped portion. We also need the transmission to never go to zero or saturate, which will enable us to relate the transmission back to the density. These two requirements place a more stringent limit on diameter of the shock tube. Using cold opacities we found that a diameter of 2.25 mm would enable us to meet our imaging requirements, while still obtaining more features. The difference in transmission between the iodine doped portion and the PAI is approximately 25%.

Sine waves with wavelength λ = 150 μm and amplitude a_0 = 4 μm are precision machined along the strip, which is aligned perpendicular to the diagnostic line of sight using 30 μm width alignment tabs at the end of the doped portion. On top of this sinusoidal pattern a broadband (noise) perturbation can be machined to drive the RMI into a nonlinear and potentially turbulent state faster.

The time of the experiment is partially dictated by the blow-out time of the tube, at which point the shocks moving laterally through the beryllium exit into the vacuum, and lateral effects can interfere with the experiment. To minimize these effects and lengthen the overall time of the experiment, the thickness of the walls was increased to 300 μm. However, increasing the tube diameter and wall thickness also increases the amount of beryllium. Due to health concerns, the amount of beryllium per shot at the NIF is limited to 19 mg. To keep below this limit the tube was changed to a top hat design, with a fluorinated plastic (CF) casing around the beryllium ends.

The CF (ρ_0 = 1.4 g/cc) was chosen for its close density match to beryllium (ρ_0 = 1.45 g/cc) so that we could use it as a replacement for beryllium while still mitigating reflections at the new CF/beryllium interface. Figure 3 shows the entire target design.

First experimental results show that the redesign from OMEGA to the NIF was successful. Figure 4 shows an example of late time NIF data (t = 27 ns). The layer in this image was initially shocked around t = 16 ns and reshocked around t = 22.5 ns. As described above a sinusoidal pattern with λ = 150 μm and amplitude a_0 = 4 μm was machined onto the layer; a small amplitude, $a \approx 1 - 2$ μ, noise perturbation was machined on top of the sinusoidal pattern. The data exhibits the same sinusoidal pattern with similar wavelength, but additional material is present in the peaks and valleys, suggesting that the low density foam and high density CH are mixing.

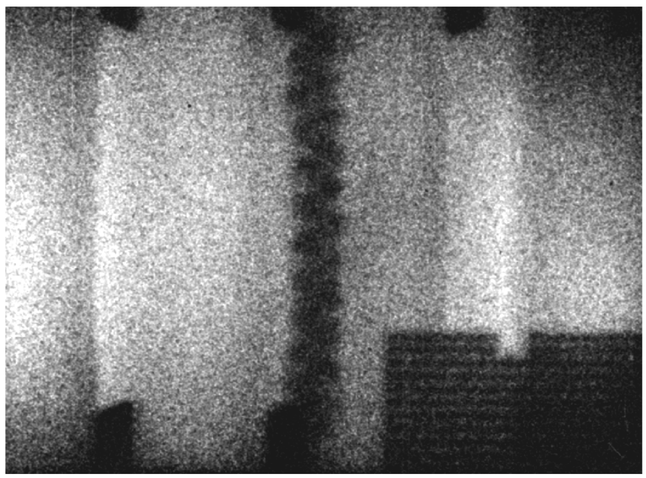

Figure 4: *Example of NIF data with the redesigned target and the strip doping of the high density layer at t = 27 ns. The layer initially had a sinusoidal perturbation with λ = 150 μm and amplitude a_0 = 4 μm and a broadband (noisy) perturbation on top of the sine wave, with amplitude around 1 – 2 μm.*

III. Summary

The OMEGA *Mshock* campaign has started on the NIF. Several target changes were necessary to facilitate the transition. The diameter of the tube was increased to increase the number of observable growth features, and thus our measurement statistics. In addition, the thickness of the tube was increased to ensure that the tube would not blow out until late times and reduce the chance of lateral effects changing the experiment. We have successfully employed a strip doping technique to highlight individual features. A linear sinusoidal pattern was machined onto the strip and the results show that at late times and post reshock the sinusoidal pattern is still visible.

Acknowledgements

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